BOLINAS LAGOON
ECOSYSTEM RESTORATION PROJECT

CIVIL DESIGN APPENDIX

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US Army Corps of Engineers
San Francisco District

BOLINAS LAGOON ENVIROMENTAL RESTORATION
CONCRETE BRIDGES FOR OPEN CHANNELS

1. General

   The two proposed open channels between Bolinas Lagoon and Seadrift Lagoon will impact existing Dipsea Road, underground power, telephone, cable TV, and water lines. Therefore, a concrete bridge will be needed at each open channel location. Most utility relocations will involve replacement or modification at the proposed bridge locations.

2. Road and Bridges

   2.1 Temporary Detours and Crossing. Detours and temporary crossing will be coordinated between the contractors and local sponsors. Due to traffic load and local desire to insure a minimum impact to traffic, a temporary detour will be provided to proposed channel excavation and bridge construction.

   2.2 Basis of Design. The proposed bridge will include the following features:
   - tapered, pre-cast concrete piles
   - cast-in-place concrete piers and abutments
   - pre-cast, pre-stressed concrete girders
   - cast-in-place concrete deck slab
   - parapet wall, railing

   Alignment of the proposed bridges will follow that of the existing Dipsea Road. Total bridge lengths will be considerably longer according to the final channel dimensions. Final designs, contract plans and specifications will be developed by the Corps of Engineers with the use of funds contributed by the local sponsors for proposed bridges to be included in the channel construction contract.

BOLINAS LAGOON ENVIROMENTAL RESTORATION
OPEN CHANNEL SHEET PILE ANALYSES

1. General

Sheet pile analyses were performed to evaluate the stability of proposed sheet pile structures for open channels of east and west Seadrift Lagoon, and the impact on some existing or proposed facilities, such as houses and bridges. These analyses were based on a review of available data and general subsurface conditions typical of each soil site provided by Geotechnical Section. Additional site or condition – specific geotechnical data as well more detailed analyses are recommended for final design.

2. Analyses

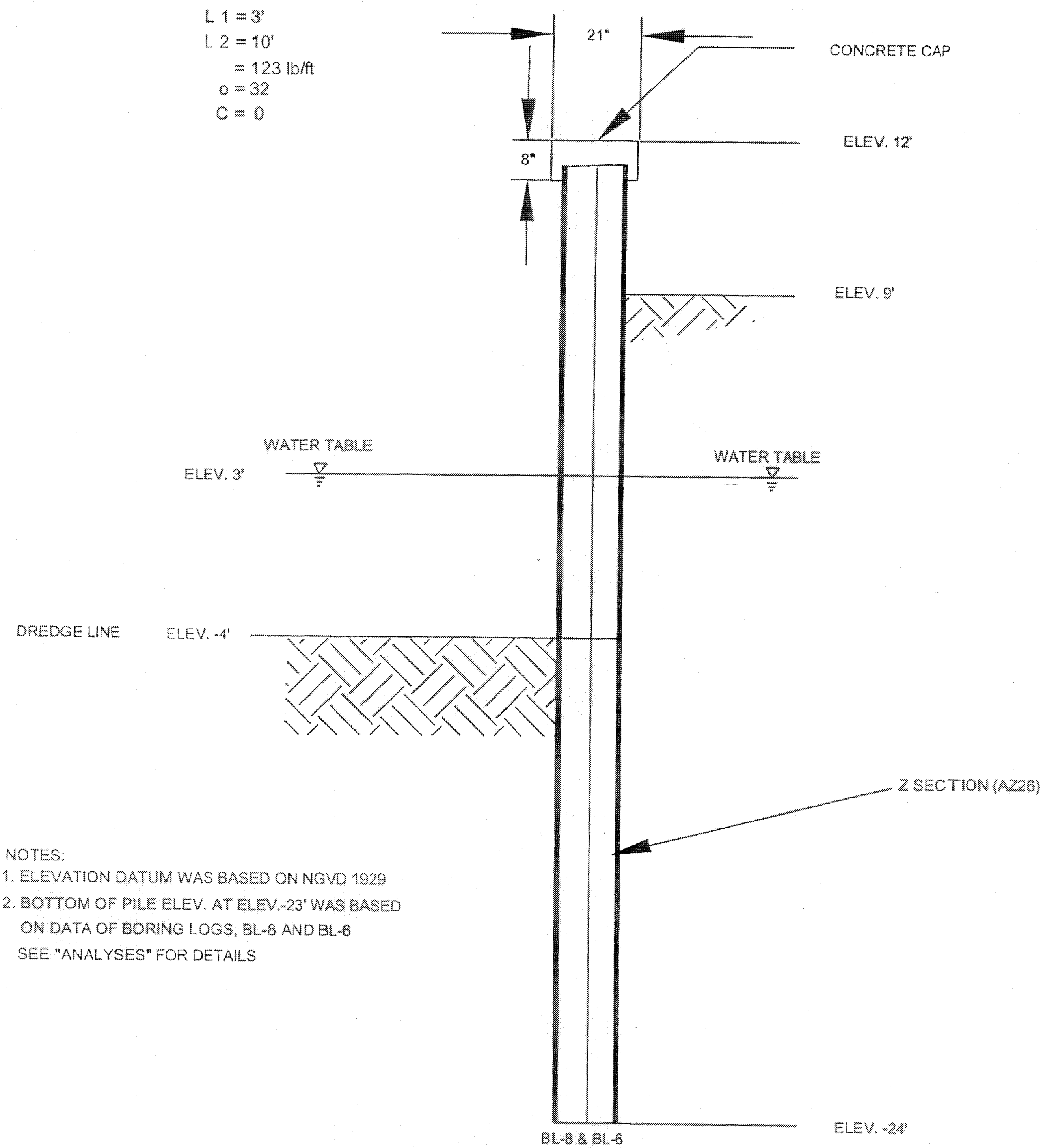
2.1 Cantilever Sheet pile Embedment Length. The relationships for the proper depth of embedment of cantilever sheet piles driven into a granular soil, and the correlation between density, soil type and load are shown on page 463 of Dr. Braja M. Das' 1998 edition of *Principles of Foundation Engineering*. Maximum bending moment and section modulus were also calculated in order to select the most effective and economical sections of the sheet piles. The analyses were based on information obtained from borings BL-2, BL-4, BL-6, and BL-8. The level of hydrostatic pressure lines from both sides of the cantilever wall were assumed that equal to the level of water table obtained from borings data.

2.2 Safety and Integrity. All calculations were based on the theory and the step-by-step procedure listed on the above reference for obtaining the pressure diagram for the cantilever sheet pile wall penetrating sandy soils. The actual depth of penetration was increased by 30%. A factor of safety of 3 was used to select the final sections of sheet piles.

2.3 Sheet pile of East Seadrift Lagoon Open Channel. The total depth of the sheet pile of East Seadrift Lagoon (Open Channel) driven into soil should not be less than 33 feet (refer to Appendix #1). The maximum bending moment is 25,574 lb-ft located at 10 feet above the bottom (Elev. –14). The section modulus required for the sheet pile is 10.3 in^3/ft for ASTM A-572 or A-690 steel. For the factor of safety of 3, an ultimate section modulus of 30.9 in^3/ft is recommended.

2.4 Sheet pile of West Seadrift Lagoon Open Channel. The total depth of the sheet pile of West Seadrift Lagoon (Open Channel) driven into soil should not be less than 36 feet (refer to Appendix #2). The maximum bending moment is

34,435 lb-ft located at 9.5 feet above the bottom (Elev. –13.5). The section modulus required for the sheet pile is 13.8 in^3/ft for ASTM A-572 or A-690 steel. For the factor of safety of 3, an ultimate section modulus of 41.4 in^3/ft is recommended.



NOTES:

1. ELEVATION DATUM WAS BASED ON NGVD 1929
2. BOTTOM OF PILE ELEV. AT ELEV.-23' WAS BASED ON DATA OF BORING LOGS, BL-8 AND BL-6 SEE "ANALYSES" FOR DETAILS

EAST SEADRIFT LAGOON SHEETPILE (OPEN CHANNEL)

NOT TO SCALE

APPENDIX # 1

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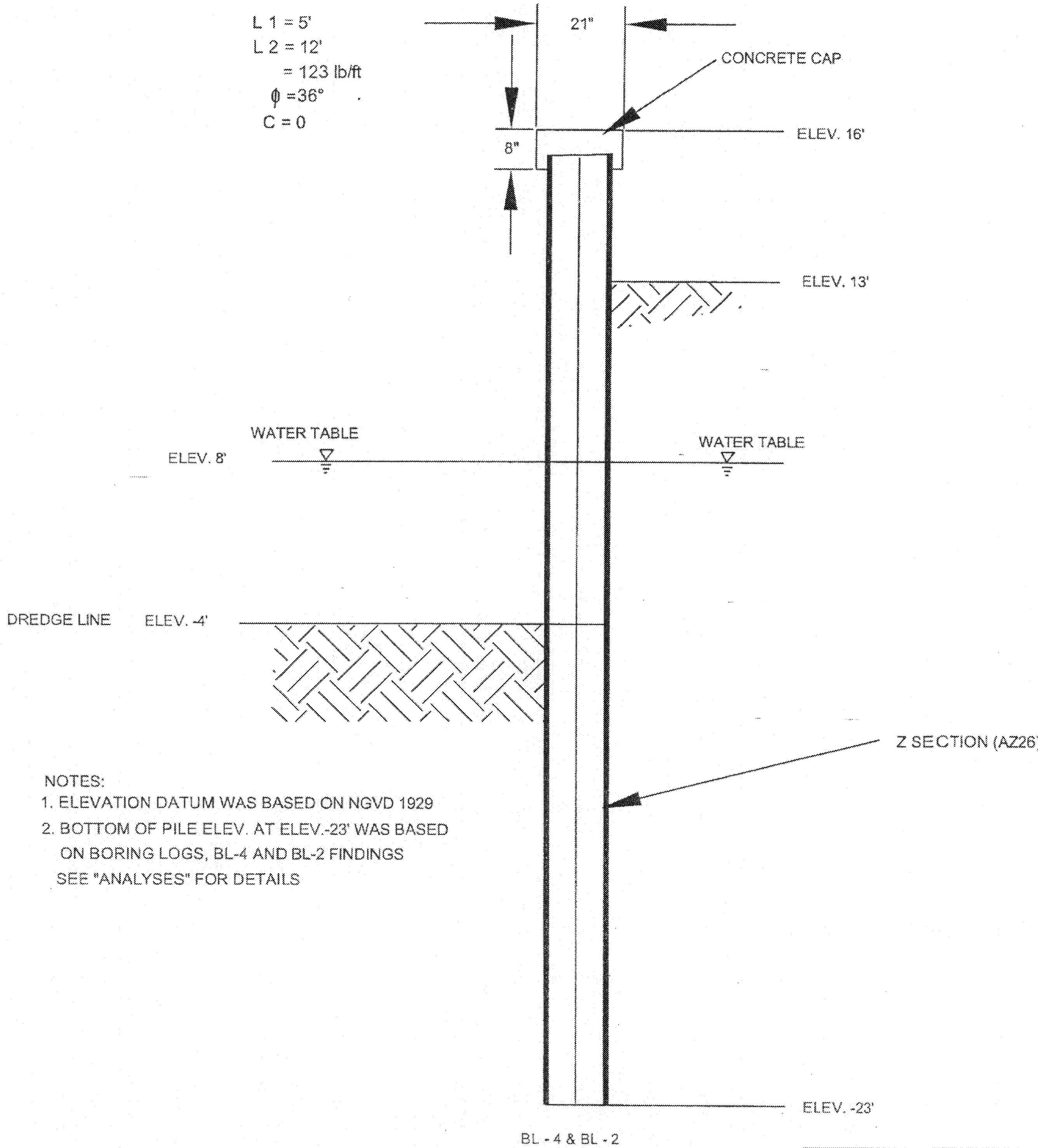
DESIGNED BY: G.F.	EAST SEADRIFT LAGOON SHEET PILE (OPEN CHANNEL)
CHECKED BY: C.B.	



NOTES:
1. ELEVATION DATUM WAS BASED ON NGVD 1929
2. BOTTOM OF PILE ELEV. AT ELEV.-23' WAS BASED ON BORING LOGS, BL-4 AND BL-2 FINDINGS SEE "ANALYSES" FOR DETAILS

WEST SEADRIFT SHEETPILE (OPEN CHANNEL)

NOT TO SCALE

APPENDIX # 2

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SAN FRANCISCO DISTRICT

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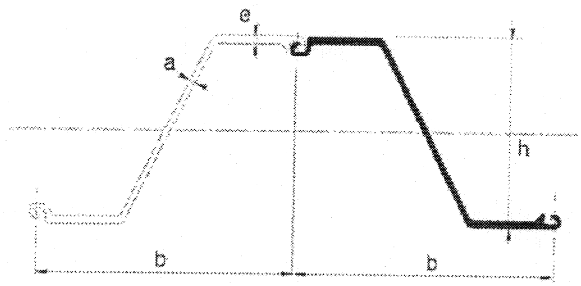
DESIGNED BY: G.F.	WEST SEADRIFT LAGOON
CHECKED BY: C.B.	SHEET PILE (OPEN CHANNEL)

Z SECTIONS



Essential characteristics of the Z sheet pile are the continuous form of the web and the specific location of the interlock symmetrically on both sides of the neutral axis, the two facts having a positive influence on the calculation on the section modulus.

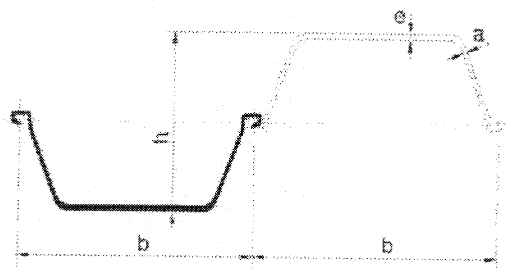
The AZ series is a combination of a section with extraordinary characteristics and the Larssen interlock with its proven qualities, presenting the following advantages:
- an extremely competitive relation section modulus/mass
- an increased inertia reducing the deflection, allowing the choice of high yield steel grades for the most economical solution
- large width resulting in high installation performance.

Show values in metric units.

Section	Dimensions				Sectional area	Mass of single pile	Mass per ft^2 of wall	Section modulus	Moment of inertia
	b	h	e	a					
	in	in	in	in	in^2/ft	lb/ft	lb/ft^2	in^3/ft	in^4/ft
AZ 13	26.38	11.93	0.375	0.375	6.47	48.38	21.92	24.2	144.3
AZ 18	24.80	14.96	0.375	0.375	7.09	49.99	24.17	33.5	250.4
AZ 26	24.80	16.81	0.512	0.480	9.35	65.72	31.75	48.4	406.5
AZ 36	24.80	18.11	0.709	0.551	11.67	82.11	39.73	67.0	606.3
AZ 48	22.83	18.98	0.748	0.591	14.48	93.81	49.28	89.3	847.1

All Z sections may be rolled up or down by 0.5 mm & 1.0 mm (AZ 48 upon request).

U SECTIONS



Since more than 80 years millions of tons of U sheet piles have been used all over the world for every kind of structures.
The advantages of U piles are multiple:
- A wide range of sections forming several series with various geometrical characteristics, offering the choice of the section technically and economically best suited for a specific project.
- The combination of great wave depth with important flange thickness giving excellent statical properties.
- The symmetrical form of the single element has made these sheets particularly convenient for re-use.
- The possibility of assembling and fixing the piles to pairs in the mill provides an improvement of the installation quality and performance.
- Easy fixing of tie rods and swivelling attachments, even under water.
- Good corrosion resistance, the biggest steel thicknesses lying on the outer part of the geometry.

Show values in metric units.

Section	Dimensions				Sectional area	Mass of single pile	Mass per ft^2 of wall	Section modulus	Moment of inertia
	b	h	e	a					
	in	in	in	in	in^2/ft	lb/ft	lb/ft^2	in^3/ft	in^4/ft
PU 6	23.62	8.9	0.295	0.252	4.58	30.64	15.57	11.2	49.6
PU 8	23.62	11.02	0.315	0.315	5.48	36.62	18.64	15.4	85.1
PU 12	23.62	14.17	0.386	0.354	6.61	44.42	22.53	22.3	158.2
PU 16	23.62	14.96	0.472	0.354	7.51	50.20	25.40	29.8	222.6
PU 20	23.62	16.93	0.488	0.394	8.46	56.65	28.67	37.2	314.9
PU 25	23.62	17.80	0.559	0.394	9.40	62.90	31.95	46.5	413.7
PU 32	23.62	17.80	0.768	0.433	11.43	76.67	38.91	59.5	529.6
L 2 S	19.69	13.39	0.484	0.354	8.36	46.84	28.47	29.8	192.2
L 3 S	19.69	15.75	0.555	0.394	9.50	53.02	32.36	37.2	293
L 4 S	19.69	17.32	0.610	0.394	10.35	57.92	35.23	46.5	402.8
JSP 2	15.75	7.87	0.413		7.23	32.25	24.58	16.3	64.0
JSP 3	15.75	9.84	0.512		9.02	40.32	30.72	24.9	123.0

$L_1 = 5'$

$L_2 = 12'$

$\gamma = 123\ LB/ft^3$

$\phi = 36°$

$C = 0$

West Seadirft Lagoon

$Ka = \tan^2(45° - \frac{\phi}{2}) = \tan^2(45 - \frac{36°}{2}) = 0.26$

$Kp = \tan^2(45 + \frac{\phi}{2}) = \tan^2(45 + \frac{36}{2}) = 3.85$

$Kp - Ka = 3.85 - 0.26 = 3.6$

$P_1 = \gamma L_1 Ka = 123 \times 5 \times 0.26 = 160\ LB/ft^2$

$P_2 = (\gamma L_1 + \gamma' L_2) Ka = (123 \times 5 + 100 \times 12) \times 0.26 = 472\ LB/ft^2$

$$L_3 = \frac{P_2}{\gamma'(Kp - Ka)} = \frac{472}{100 \times 3.6} = 1.31\ ft$$

$$P = \frac{1}{2} P_1 L_1 + P_1 L_2 + \frac{1}{2}(P_2 - P_1) L_2 + \frac{1}{2} P_2 L_3$$

$$P = \frac{1}{2} \times 160 \times 5 + 160 \times 12 + \frac{1}{2}(472 - 160) + \frac{1}{2} \times 472 \times 1.31 = 2785\ LB/ft$$

$$\bar{Z} = \frac{\Sigma M_c}{P} = \frac{1}{2785} \{400(1.31 + 12 + \frac{5}{3}) + 1920(1.31 + \frac{12}{2}) + 156(1.31 + \frac{12}{3}) + 309(1.31 \times \frac{2}{3}) = 7.82\ ft$$

$$P_5 = (\gamma L_1 + \gamma' L_2) K_p + \gamma' L_3 (K_p - Ka) = (123 \times 5 + 100 \times 10) 3.85 + (100 \times 1.31 \times 3.6) = 6690$$

$$A_1 = \frac{P_5}{\gamma'(K_p-K_a)} = \frac{6690}{100 \times 3.6} = 18.6$$

$$A_2 = \frac{8P}{\gamma'(K_p-K_a)} = \frac{8 \times 2785}{100 \times 3.6} = 61.9$$

$$A_3 = \frac{6P[2\bar{z}\gamma'(K_p-K_a)+P_5]}{\gamma'^2(K_p-K_a)} = \frac{6 \times 2785(2 \times 7.82 \times 100 \times 3.6)+6690}{100^2 \times 3.6} = 2613.6$$

$$A_4 = \frac{P(6\bar{z}P_5+4P)}{\gamma'^2(K_p-K_a)} = \frac{2785(6 \times 7.82 \times 6690 + 4 \times 2785)}{100^2 \times 3.6} = 25145$$

$$L^4 + 18.6L^3 - 61.9L^2 - 2613.6L - 25145 = 0$$

Solve for $L = 13.01$ ft $\quad L + L_3 = 13.01 + 1.31 = 14.32'$

$L+D = 17 + 1.3(14.32) = 35.62$ ft $\approx \boxed{36 \text{ feet}}$

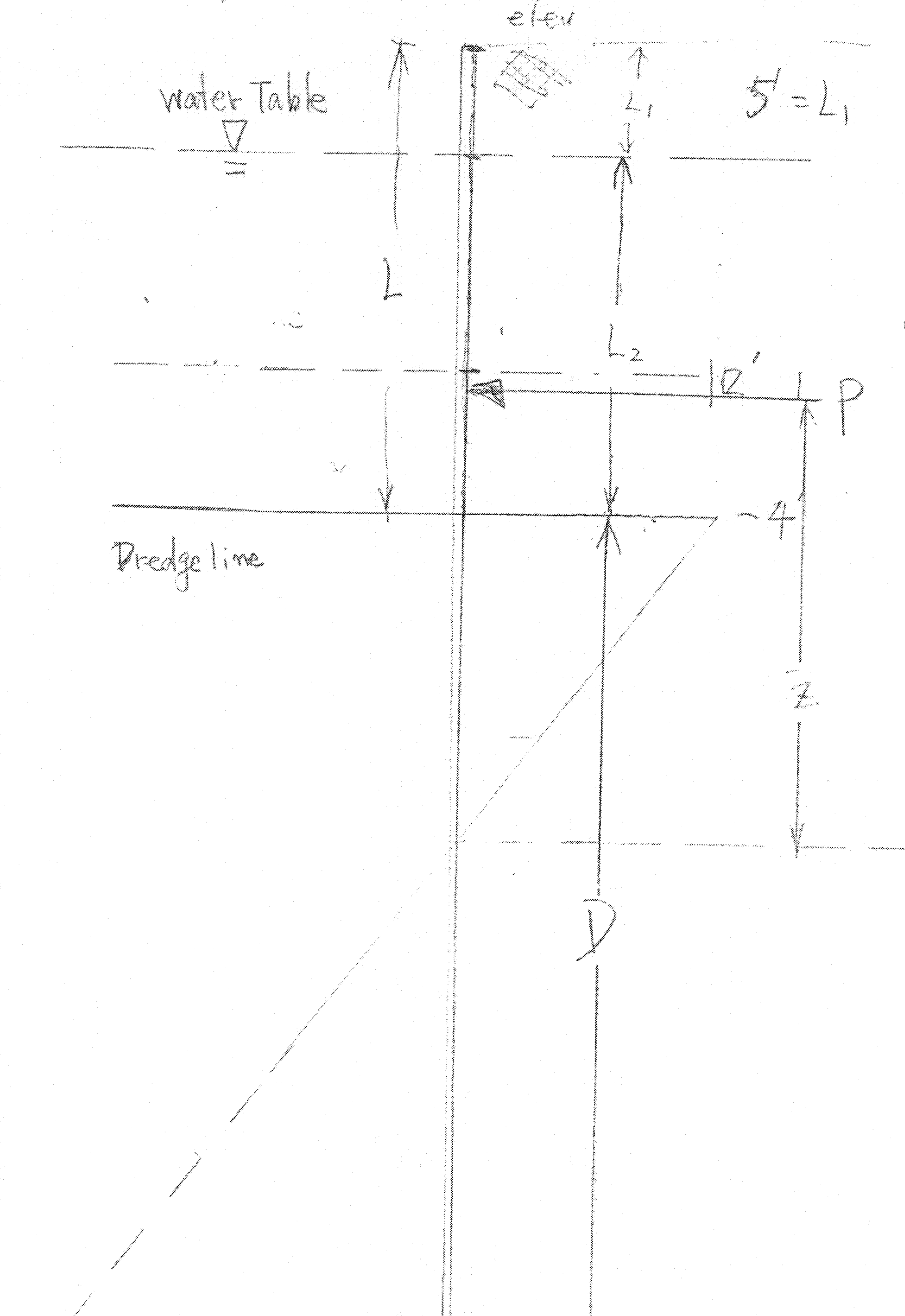
$$z' = \sqrt{\frac{2P}{\gamma(K_p-K_a)}} = \sqrt{\frac{2 \times 2785}{123(3.6)}} = 3.55 \text{ feet}$$

$$M_{max} = P(\bar{z}+z') - \frac{\gamma z'^3(K_p-K_a)}{6} = 2785(10+3.55) - \frac{123 \times 3.55^3 \times 3.6}{6}$$

$$\boxed{M_{max} = 34435 \text{ LB-ft}}$$

Section Modulus

$$S = \frac{M}{\sigma} = \frac{12'' \times 34435}{30{,}000} = \boxed{13.8 \approx 14 \text{ in}^3/\text{ft}}$$



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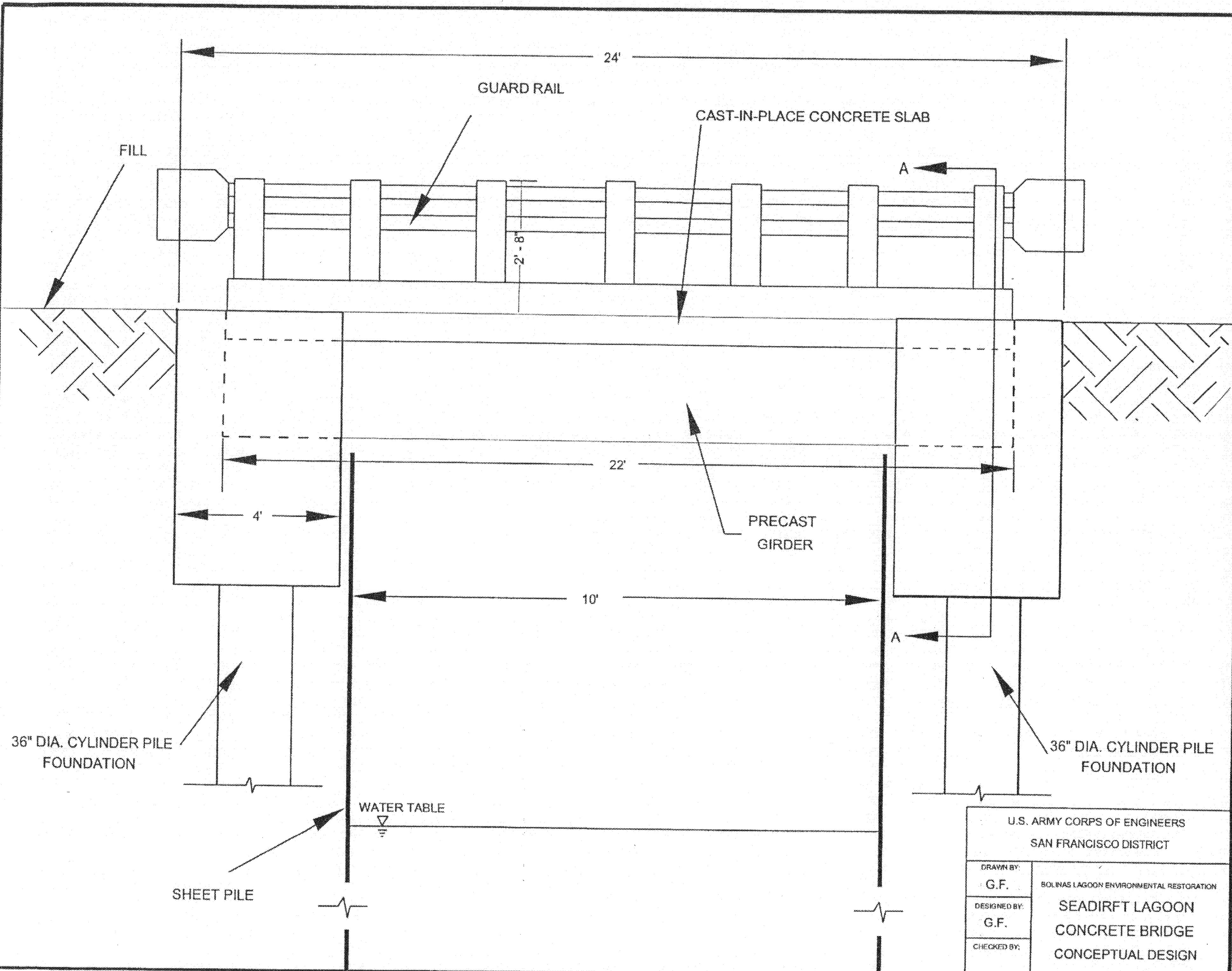
24'
GUARD RAIL
CAST-IN-PLACE CONCRETE SLAB
FILL
A
2' - 8"
22'
4'
PRECAST
GIRDER
10'
A
36" DIA. CYLINDER PILE
FOUNDATION
36" DIA. CYLINDER PILE
FOUNDATION
WATER TABLE
SHEET PILE
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SAN FRANCISCO DISTRICT
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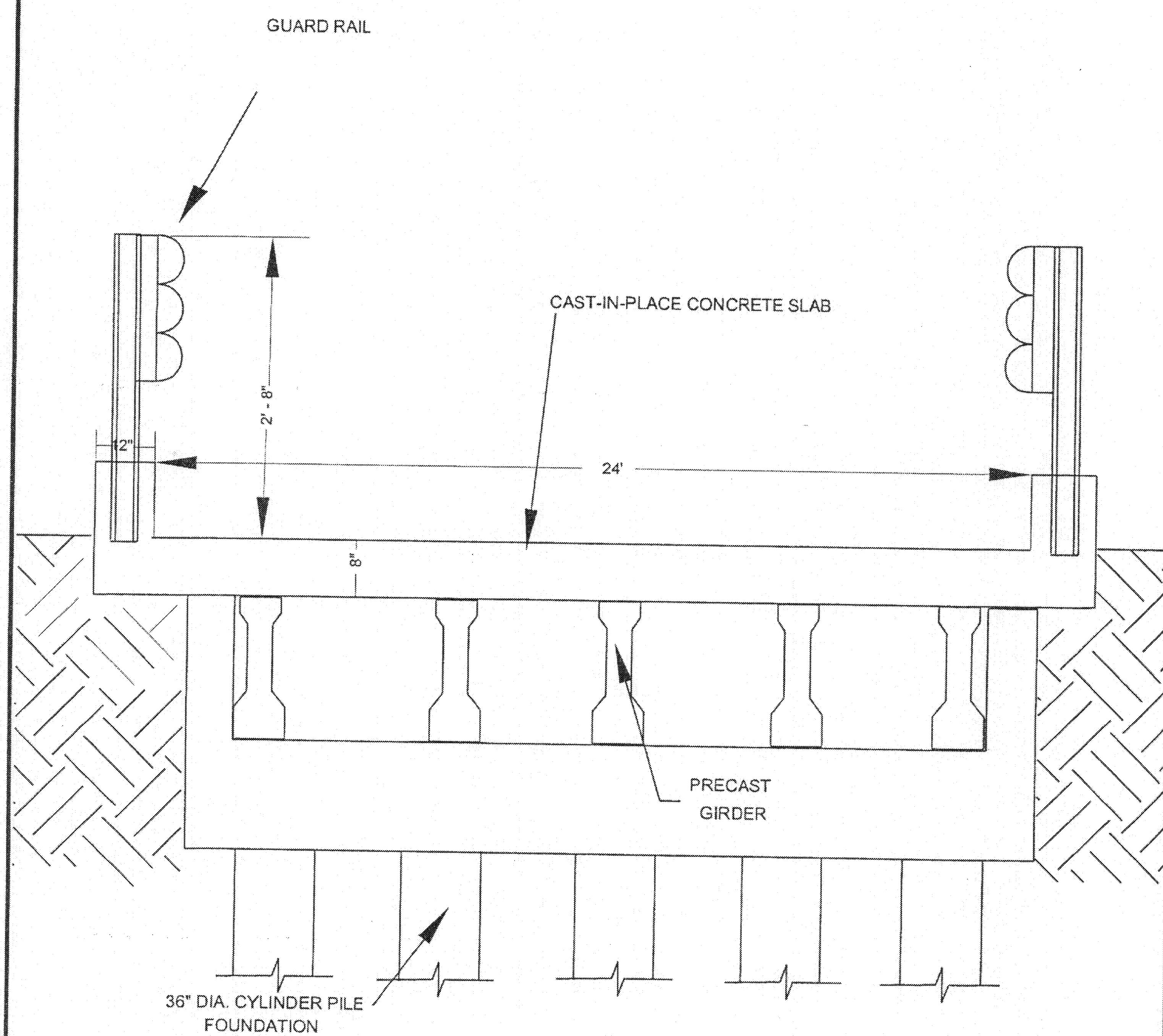
G.F.
DESIGNED BY:
G.F.
CHECKED BY:
BOLINAS LAGOON ENVIRONMENTAL RESTORATION
SEADIRFT LAGOON
CONCRETE BRIDGE
CONCEPTUAL DESIGN



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SAN FRANCISCO DISTRICT

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